# “Design and Analysis of Power Management Model for Hybrid Generation Systems”

**SHORT SYNOPSIS**

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## FACULTY OF ENGINEERING AND TECHNOLOGY

# Certificate

I hereby declare that the short synopsis **"Design and Analysis of Energy Management System for Hybrid Generation Systems"** being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in Electrical and Electronics Department under faculty of Engineering and Technology of Manav Rachna International Institute of Research & Studies, Faridabad during the academic year 2018-2019

It is a bona fide record of original work carried out under the supervision of Dr. Anita Khosla & Joint-Supervisor Dr. Dheeraj Joshi and has not been submitted in full or part to any other university or institute for degree or diploma. Further, it is certified that short synopsis is plagiarism free and proof has been submitted.

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## Abstract

Global warming and gradual consumption of conventional sources have led to significant research in the area of green sources like Solar and wind. The solar and wind supplying system are suitable only to feed local loads. The drawback of using such system is their dependency on weather conditions. Still, there is upsurge in usage of non-conventional resources in the existing power system. However it poses to high technical challenges when used alone without conventional power systems & improper energy storage systems. In this research, energy supply system will be proposed to match energy demand by taking some operational constraints with integration of two or more energy sources that is "hybrid power system (HPS)".HPS will be photovoltaic cell based which will be further examined with artificial intelligent control techniques. The essential point of this examination will be to build up energy Management system based on forecasting of energy requirements and previous measurements for few inexhaustible energy sources using PVsyst and MATLAB. The proposed optimization technique will be intended to streamline the power flow between different energy sources. Simulations and algorithms will be demonstrated using MATLAB software to validate the design. The study will indicate the suitability of the developed model to smooth functioning of the "HPS" in diverse load conditions.



Keywords: —photovoltaic cells, battery, hybrid power systems, energy management, energy Storage systems, wind/ photovoltaic (PV)/Fuel cell (FC).

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## 1. Introduction

In recent years, pollution due to consumption of conventional sources fuel causes major problems globally. Due to these adverse effects green sources are going to replace conventional sources of energy. The green sources are available in abundance.

Among all renewable energies available, “Wind energy conversion systems (WT) and Photovoltaic (PV)” systems are widely used in recent years. However, the unpredictable behaviors of these two systems make them complex especially in hybrid applications. To overcome this problem large battery banks such as super capacitors etc.

Modern static devices such as Fuel Cell (FCs) power generation systems which produce power from electrochemical process. These systems behave like batteries and by using FC’s hybrid generation system will become more reliable. A lot of research is being done on dynamic behavior and power management of Hybrid Power systems (HPS). . The adequate control of hybrid Power system(HES) is main challenge behind its operation. The lack of control system brings it to non-sustainable scenarios, in which hybrid systems can be implemented but with high operation costs and out of sustainability scenarios. As a consequence, technical requirements should be applied not only to design hybrid systems but also to create the best Power Management Model.

The Energy management model proposed for the HPS is to synchronize the power by different energy sources and load.

HPS is compounded by some elements identified as subsystems:
- Solar cells (photovoltaic cells).
- Electrolyzer (hydrogen production + storage system).
- Fuel cell stack.
- DC bus and DC electrical load.

DC load is represented by telecommunication systems (DC equipment for security systems).
As mentioned above, HPS operation is generally coordinated by using Energy management system, which uses a controller to coordinate the combined operation of solar cells, Electrolyzer and fuel cells in order to get sustainability and uninterrupted power to different DC loads.

EMS is based on a mathematical approach and block diagrams of EMS components. Additionally it is necessary to establish some initial conditions for the EMS design process:

- Load criteria,
- Subsystems sizing (photovoltaic modules, electrolyze and hydrogen storage tank, fuel cell),
- Control criteria, which are grounded on the continuous flow of power between sources of energy and to the load; in general, Pnet.
- EMS has to be adequate in order to minimize hybrid system operation costs is defined as sum of all sources' contribution and all loads, at a specific time.

The design of EMS depends on the electrical demand achieved by minimizing the cost function, which is based on hourly operational cost of the hybrid system. This function will be identified as CT. CT is the sum of capital and maintenance hourly cost.

$$C_T = C_C + C_M$$

These costs can be broken up into the hourly costs for photovoltaic array, "electrolyzer –hydrogen storage and fuel cell stack subsystems".

The disparity in net power on hourly basis will be done by diminishing the objective function $C_T$ EMS design involves minimizing the Photovoltaic/Fuel Cell.Hybrid Energy System (PFHES) cost function under EMS model implementation, which is one of the main purposes of this research work.

## 2. Literature Review

The research documents describe methodologies to model Hybrid Systems components, Hybrid System designs and its evaluation. Authors referenced sustainable power source frameworks demonstrating, and showing its prominence.

An "AC Micro-Grid structure", depends upon "diesel motor, synchronous generator and Hybrid Energy Storage (HES)" framework, comprising "battery and ultra-capacitor" was discussed by the authors (Hassan et al.2016). This framework, "diesel generator" fills single potential source of "Micro Grid" at standalone conditions and "HPS" coordinate to accomplish the capacity of framework. Comparison of "energy management strategies" were found & net intensity of Micro grid is isolated and components of hertz are in defined in range.

For smaller scale network, magnificent algorithm is developed by the researchers (Conteh et.al 2017) on "energy management system "for calculation with respect to the power generation, control, quality issues and utilization in the power system. The primary goal of the "energy

management system “is to limit the framework cost just as taking care of the demand. So as to consider the vulnerabilities of Distributed generators (DGs) and load utilization, demand side management and load shedding is considered.

Ideal distribution of power system by joining “photovoltaic (PV) array, a fuel cell (FC) stack, an ultra-capacitor (UC) module &load is presented by the investigators (Kamal et al. 2016) . “Fuel Cell (FC)” framework is added as a reinforcement in conjunction with Solar to take care of the abundance control demand. The viability of the proposed model regarding control exchange, power transfer, voltage regulation and stability of grid is confirmed by" Matlab Simulation" results.

The experiments performed by authors ( Sawle et al. 2016), contextual analysis of comparative various “standalone hybrid combinations” for remote territory Barwani, India and discovered PV– Wind– Battery HES combinations is the most ideal arrangement with respect to cost and discharge among all different crossover framework blends. This paper additionally includes a portion for future upgrades, which really has the likelihood to enhance the strategies for the compensation on consumer side.

The best approach of “hybrid power system” is given by the authors ( Rohani et al. July 2010) for the inaccessible clients. He focuses on sustainable “hybrid power system” that acquire independent configuration with updated sizes of apparatus & economically lowering the expenses. Major generation of the “hybrid power system “originates from “photovoltaic panels and wind generators”, utilizing energy unit and batteries. Technique of programming utilized is “HOMER”. “HOMER” is software that decides ideal engineering technique of the “hybrid power system”. Experimental outcomes shows “hybrid power system” designed would be a best solution for “standalone power systems” applications at remote areas.

An independent conveyed HES control framework which comprises of solar oriented power, wind control, battery stockpiling and the load is proposed by researchers (Shen et al.2014). A control procedure is acquainted with expand the concurrent vitality collecting from both sustainable sources. The controller results in five possible contingencies according to power generated by each sustainable power input & condition of energizing of equipment. An intelligent controller is proposed to achieve the source type allotments and equalization of energy in the working possibilities. Reenactment results exhibit precise task of administrative controller& usefulness of “maximum power point tracking (MPPT) ” calculation for sunlight & wind control.

The authors (Zhou in et.al 2010) described in their research, a "dc-coupled wind/hydrogen/super capacitor hybrid power system". Additional services to the generation grid is provided by "Wind induction generator". control system ought to adjusted incorporate the "power management systems".

The experiments by researchers ( Dahmane in et. al 2015) proposed a design for directing the power stream between the generated and the power consumed by a "Wind/solar/battery" so as to fulfill the required demand (one family house). The picked methodology thinks about the induction "Wind generator (WG)" and the "photovoltaic panel (PV)" as major energy the "battery bank (BS )" as Power system. For the power source crisis, it utilizes the diesel motor (DE) as an extra source. So as to approve the proposed technique under genuine circumstances, estimations of the climate conditions and the power utilization information of an individual house are considered. The execution results are featured to exhibit the plausibility of methodology.

The investigator (Nehrir 2011, highlighted a few essential issues and challenges within the layout and electricity management of "hybrid RE/AE structures". System configurations, Storage systems, generation unit sizing, and energy management. Statistics at the present day repute and future trend of renewable strength era, in addition to a few crucial demanding situations going through the enormous deployment of RE/AE power technology and vision for destiny research in this vicinity are also provided.

The observer (Jianing et al. 2015) reviewed the current status of the simulation, optimization and control technologies for the "stand-alone wind solar energy systems "structures with battery or advanced storage. It is determined that persisted studies and improvement attempt on this area remains needed for enhancing the systems' performance, setting up strategies for precisely anticipating their yield and dependably coordinating them with various inexhaustible or regular energy assets..

In this paper (Fadaee 2012), gives a top level view of carried out multi-objective techniques via the usage of evolution algorithms for "hybrid renewable energy systems" became proposed to help the present and future research works. The end result indicates that optimization of many items in a hybrid device by means of these algorithms are "Genetic algorithm" and "particle swarm optimization".

The authors (Caisheng Wang et.al 2008) proposes an ac-connected "hybrid wind/ photovoltaic (PV)/Fuel cell (FC) alternative energy system" for "battery/standalone applications". "Wind and PV" are the major strength assets of the system, and an "FC–electrolyzer" mixture is used as a

backup and a “protracted-time period storage system”. A “power management strategy” is designed for the system to manipulate power flows with diverse “energy sources system” in the machine. Execution representation for the “hybrid electric system” has been evolved the usage of “MATLAB/Simulink”.

## 3. Gap Identified

The demand of electricity is increasing day by day. The available sources are not able to match the existing load demand .So use of renewable sources with conventional power plant is the major area of research these days. Although for remote areas small scale standalone systems can be used where conventional plants are impractical to be installed. In the previous studies researchers found that for standalone system are dependent on weather conditions which not only affects the power but also the cost of system. So there is need to design a system with real time monitoring and control of parameters such as temperature, irradiance etc. which increase power efficiency along with effective cost of the system.

In the previous research, the integration of inexhaustible sources with existing power plants is inefficient due to poor transient response and dynamic behavior of loads. The technique must be developed which results in improvement of the time response of the system.

Hybrid Power system based on Photovoltaic cells use converters to convert DC generated power into AC power using the charge controllers. The output power gets affected due to position of sun during the day and night which may further be enhanced using the different methods of maximum power point tracking (MPPT). The advanced technique such as fuzzy, Particle swarm optimization (PSO) may be used to track the maximum power.

## 4. Description of Broad Area

The worldwide issues of a quickly rising “CO2-fixation” in the environment, the “green-house impact” and the extreme rise in temperature and world atmosphere must be tended to get rapid solution. The main arrangement will be a speedy advancement from the obsolete regular energy system to a sensible, 100%-supportable power source framework. Therefore, PV Wind along with fuel cell dissemination system shall developed fast to save the environment. The geographical site based PV , and wind variation in power data will be monitored on annually or hourly basis , utilizing an assortment of most recent advances, for example, "Demand side management", grid expansion or energy accumulation (Pahlevani et. al 2016).In reality, Indian energy divisions are searching for variables, to explain the issue of security of energy supply and endeavor to pursue

environmentally friendly power system. To prevail on this scenario it is important to implement a hybrid power system generation.

Hybrid photovoltaic/power module energy system has been studied thoroughly (Lahyani et. al 2013). Solar energy systems are generally utilized as a alternative energy source and, to reduce the issue of irregular “power generation, photovoltaic power systems” could be incorporated with other “optional/sustainable power sources”. Fuel cells are another alternative source along with solar power which is highly adaptive to generate power. Energy storage is major concern while generating power from such sources because of the intermittent nature of solar power generation. Customarily, intense series of “lead acid batteries” have been utilized as the methods for “energy storage”. Due to environmental concerns related with the “management of batteries”; different choices are characterized for this application. “Fuel Cells (FCs)”, in mix with an “electrolyzer (for hydrogen generation) and hydrogen storage tanks”, have been developed (Das et. al 2017). To overcome the issues Hybrid system will be designed to transmit energy satisfactorily. With absence of Power Management tool that manage the flow of power from different sources and will not affect load sharing and its operating cost. There are many structure issues in PMM configuration process. A persistent DC load must be supplied to the system to check the consistency of the system. The Cost analysis of solar, wind and electrolyser based hybrid system will be examined and results will be simulated.

Specialized execution requires sufficient control to meet least load necessities 24 hours every day. In this thesis, not only power flows simulation but also “Hybrid energy system” unit sizing and economic Analysis of number of storage technologies based on “electrical, mechanical, chemical and thermal energy” standards will be accessed with very unique specialized parameters and working qualities (Mahmoudian et. al 2015). Current framework examination contemplates exhibit energy storage on a short, mid and long haul time scale .At this point, the usage of the “hybrid energy storage system (HESS)” approach , incorporating capacity innovations with strengthening working attributes, can be exceptionally valuable. Research will focuses around “HESS-applications, energy storage coupling designs and essential energy management systems” and also presents a guideline control system dependent on “peak shaving and low-pass filtering”. Four HESS setups, reasonable for the application in decentralized PV-frameworks: “a)power-to-heat/battery, b) power-to heat/battery/hydrogen, c) super capacitor/battery and d) battery/battery, are briefly discussed”.

Consequences of a writing survey show a significant number of promising "HESS-applications",

e.g.: " HESS in hybrid and fuel cell powered electric vehicles" (Ahmadi et. al 2018).

"HESS-applications" in self sustained energy supply systems based on "a battery/hydrogen combination".

"Grid-connected HESS" on region level or small scale level mainly districts, remote areas and household applications.

"HESS "for large scale level are mainly wind and PV Power Plant Park.

Other specific "HESS-configurations, e.g. SMES/battery, CAES/battery and flywheel/battery".

## 5. Problem Identification

Previous Research work has explained "optimization techniques for Hybrid Power Systems. In all conservative methods to optimize Hybrid Power Systems (HPS) the parameters such as weather conditions, irradiance and transient response need to be controlled. This is done as weather conditions make the system unstable & reduce the tracking efficiency to around 70%. Also the harmonics in transient response get increased and there is high noise propensity due to change in irradiance.

The intention is to develop the energy management system for the HPS which will improve the overall efficiency of the system by monitoring the parameters which changes with environmental conditions and to choose reliable methods of storing the energy. The artificial techniques will be applied to integrate the system and the controller will be optimized for the HPS.

## 6. Objectives of Research

To achieve the above mentioned aim, research objectives are outlined below:

1. To review different renewable sources based hybrid power generation plants.
2. To implement the characteristics curves based on environmental conditions such as temperature, irradiance etc. on the simulation Platform "PVsyst and MATLAB"
3. To develop a generalized PV Power Plant model in MATLAB.
4. To analyze the behavior of designed power plant under load conditions.
5. To develop hybrid power system models.
6. To optimize hybrid system models using artificial intelligent technique.

## 7. Methodology to be adopted

Following procedure will be adopted to carry the research:

1. Review the existing hybrid power system technologies.
2. To integrate conventional power system with renewable source based generation.
3. Modelling & Simulation of the stand-alone and grid connected conventional Power system with Photovoltaic based hybrid power system.
4. Development of the control algorithm for hybrid Power system using appropriate optimization technique.
5. Validation of algorithm developed for hybrid power system under diverse and balanced load conditions.

## 8. Expected Outcome of the Research

There are valuable outcomes of this research work could make to the engineering area:

- General advantages of Energy Management modules can be implemented as part of large-scale hybrid energy systems.
- Energy Management Modules application can have positive effects on hybrid systems' component sizing and operation costs.
- The implementation of the Power Management module idea could be employed for systems that include critical DC applications (i.e. Telecommunications systems, transportation) and other AC applications.
- Power Management Model could be implemented to coordinate hybrid energy system performance, in which sufficient electricity is supplied to a DC load, under adequate schedule, weather and power management network conditions.

## 9. Proposed Time Frame

| Time Frame | Dec 16-June 17 | | | July-Dec 17 | | | Jan -June 18 | | | July-Dec 18 | | | Jan-June 2019 | | | July-Dec 19 | | | Mar 2020 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Months | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 37 | 38 | 39 |
| Course Work | | | | | | | | | | | | | | | | | | | | | |
| Extensive Literature Survey | | | | | | | | | | | | | | | | | | | | | |
| Problem Statement | | | | | | | | | | | | | | | | | | | | | |
| "hybrid power system operation principles and methods used for hybrid system optimization " | | | | | | | | | | | | | | | | | | | | | |
| Simulation of PV Power Plant | | | | | | | | | | | | | | | | | | | | | |
| Simulation of wind Energy conversion system | | | | | | | | | | | | | | | | | | | | | |
| Develop and Analyze Standalone and Grid connected Hybrid system | | | | | | | | | | | | | | | | | | | | | |
| Develop algorithm for Optimum sizing and Management with energy storage system | | | | | | | | | | | | | | | | | | | | | |
| Publication Related to the work | | | | | | | | | | | | | | | | | | | | | |
| Detail Writing and submission report | | | | | | | | | | | | | | | | | | | | | |

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